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Time Domain Reflectometry for Evaluating Detonator Cable Assemblies in the NEP

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Time Domain Reflectometry for Evaluating Detonator Cable Assemblies in the NEP

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Initiation Systems Group

Lawrence Livermore National Laboratory

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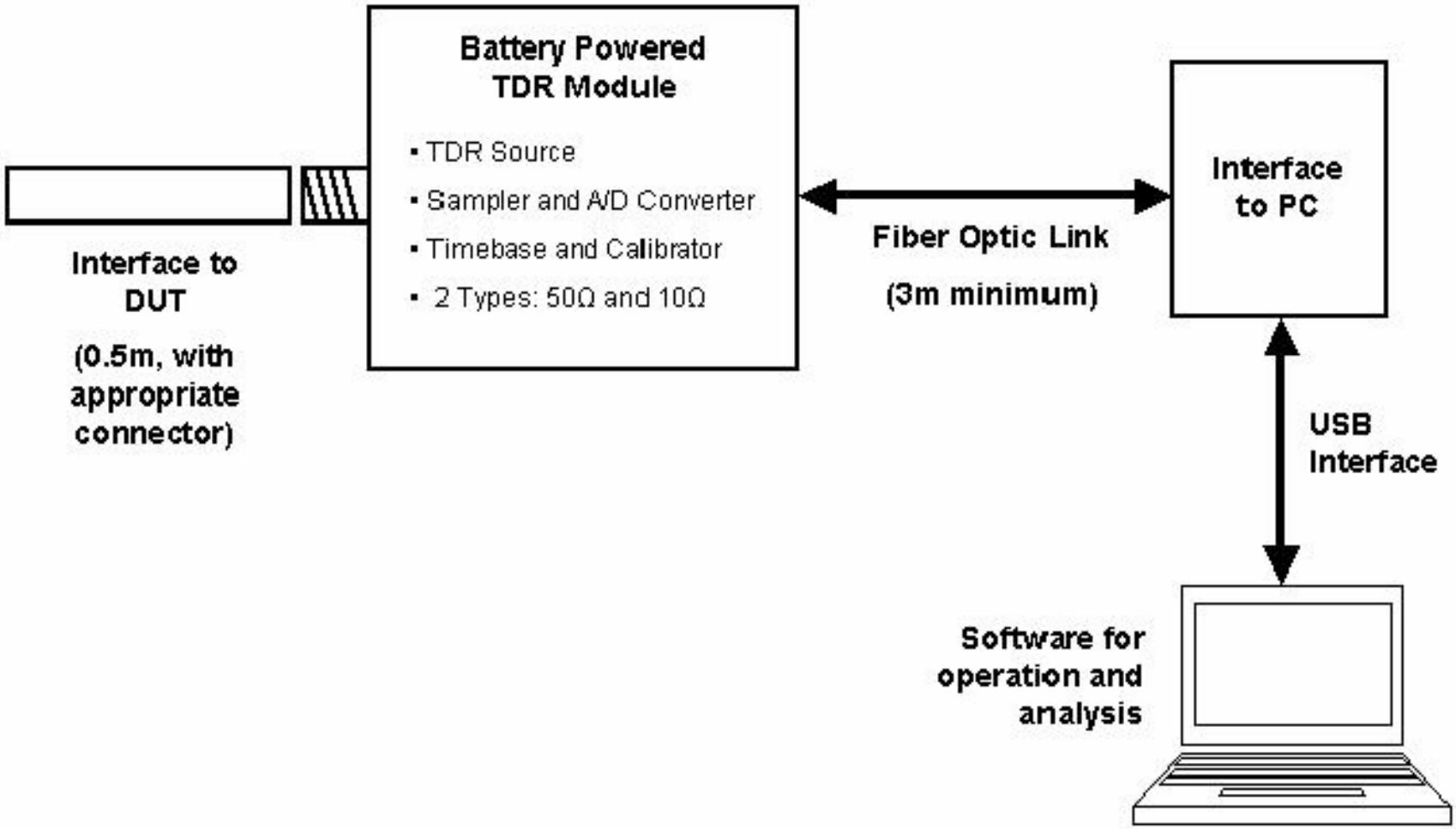
NNSA ADAPT NDE TDR Program

- **Develop Non-Destructive Evaluation (NDE) Method to Determine the Integrity of Detonator Cable Assemblies (DCAs) in Weapons.**
- **Hardware Development:**
  - **Develop Time Domain Reflectometry (TDR) methods to provide a high fidelity investigative technique for DCA integrity, that**
  - **Meets the safety requirements for use on nuclear weapons.**
- **Software Development:**
  - **Perform an experimental program to determine various cable insults that compromise DCA integrity in the weapon,**
  - **Develop analysis software to convert TDR signal to "Go/No-Go" information.**

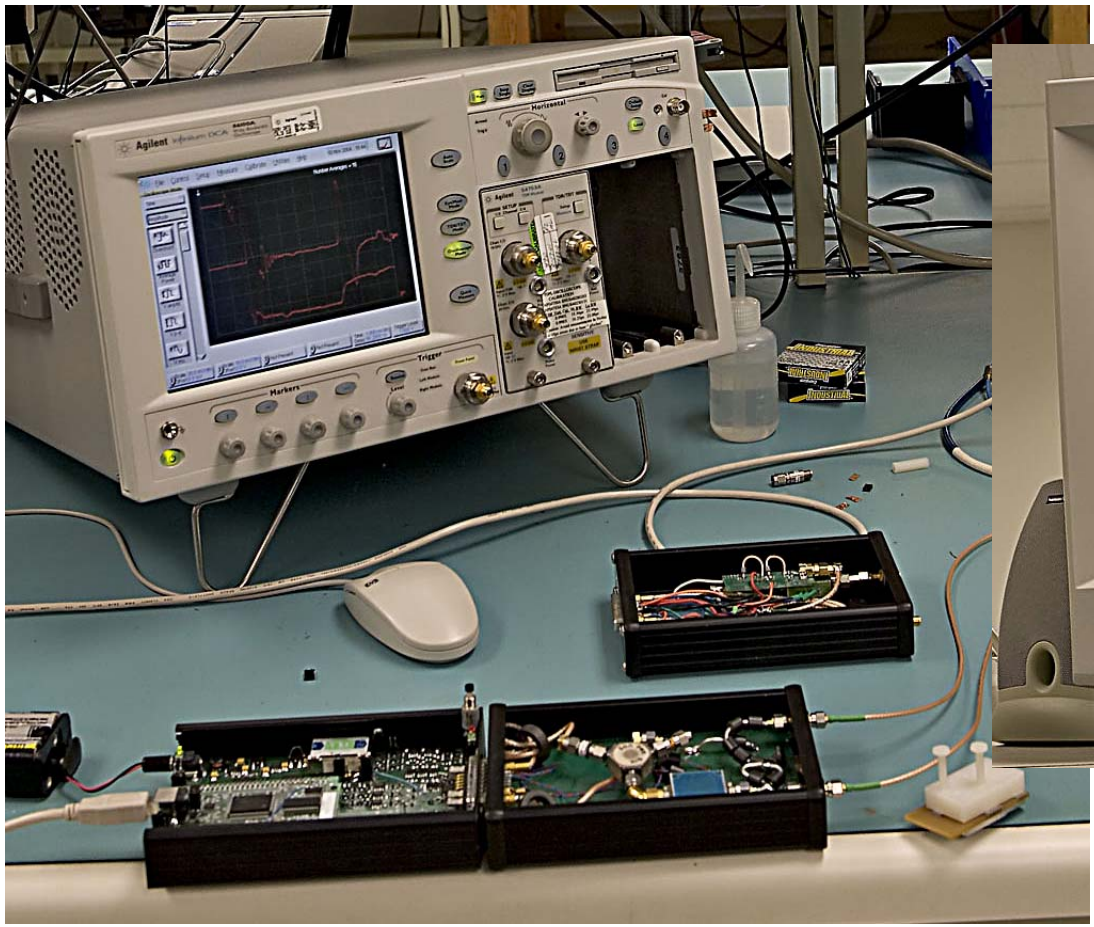
Experimental and Development Plan

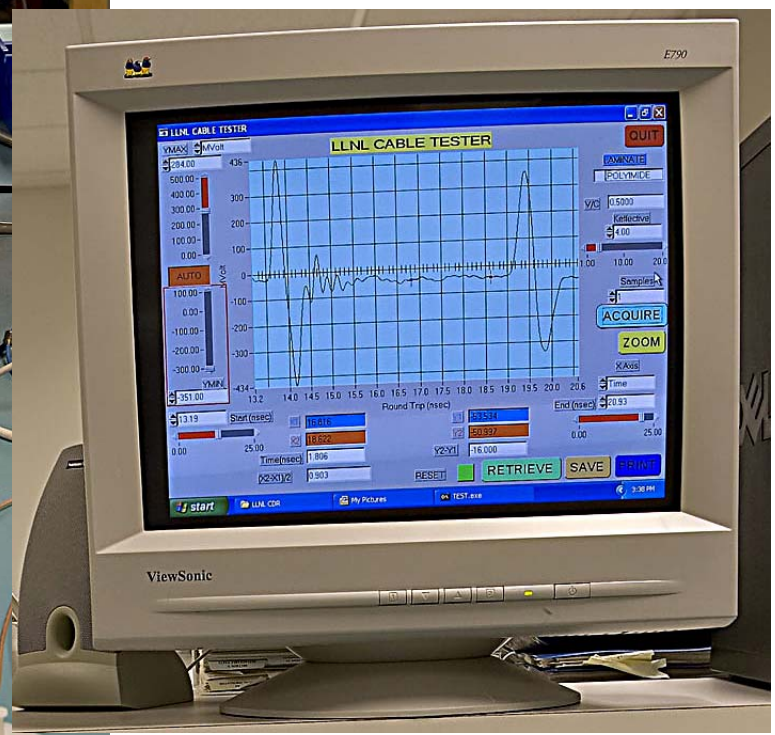
- **Phase I (LLNL): Proof of Concept (Finished)**
  - **Develop a physical breadboard system that provides a test vehicle for the proof of concept.**
  - **Perform experiments to measure and evaluate know cable insults and determine impact on DCA performance.**
- **Phase II (LLNL): Development of an Engineering Prototype (Delivery 08/05)**
  - **Build an engineering prototype for extensive functional and safety evaluation.**
  - **Develop analysis and operational software for TDR prototype.**
- **Phase III (Pantex): Fabrication of Production Units**
  - **Vendor to build TDR production DCA testers.**

System Block Diagram

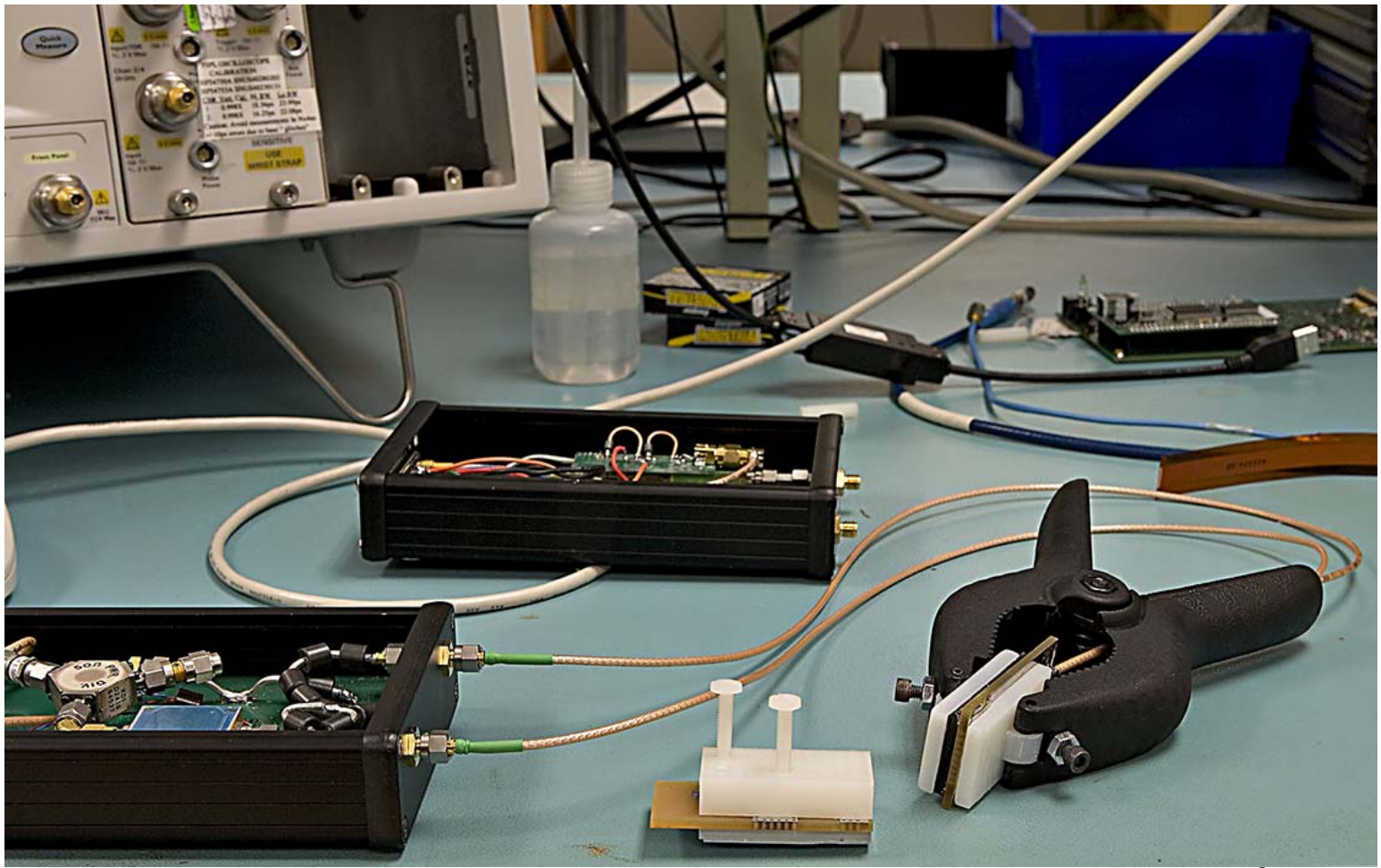


Breadboard TDR at PSPL

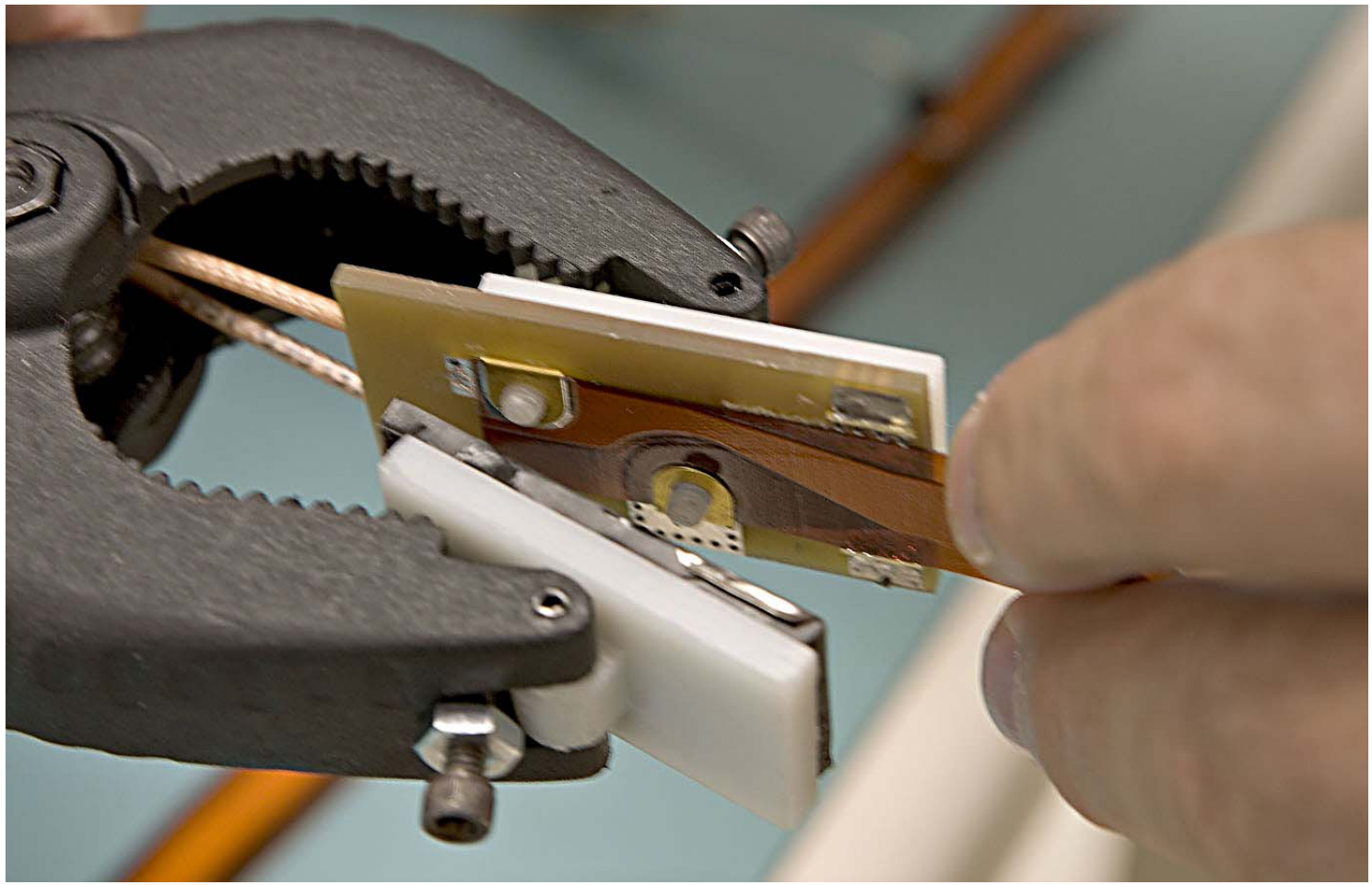




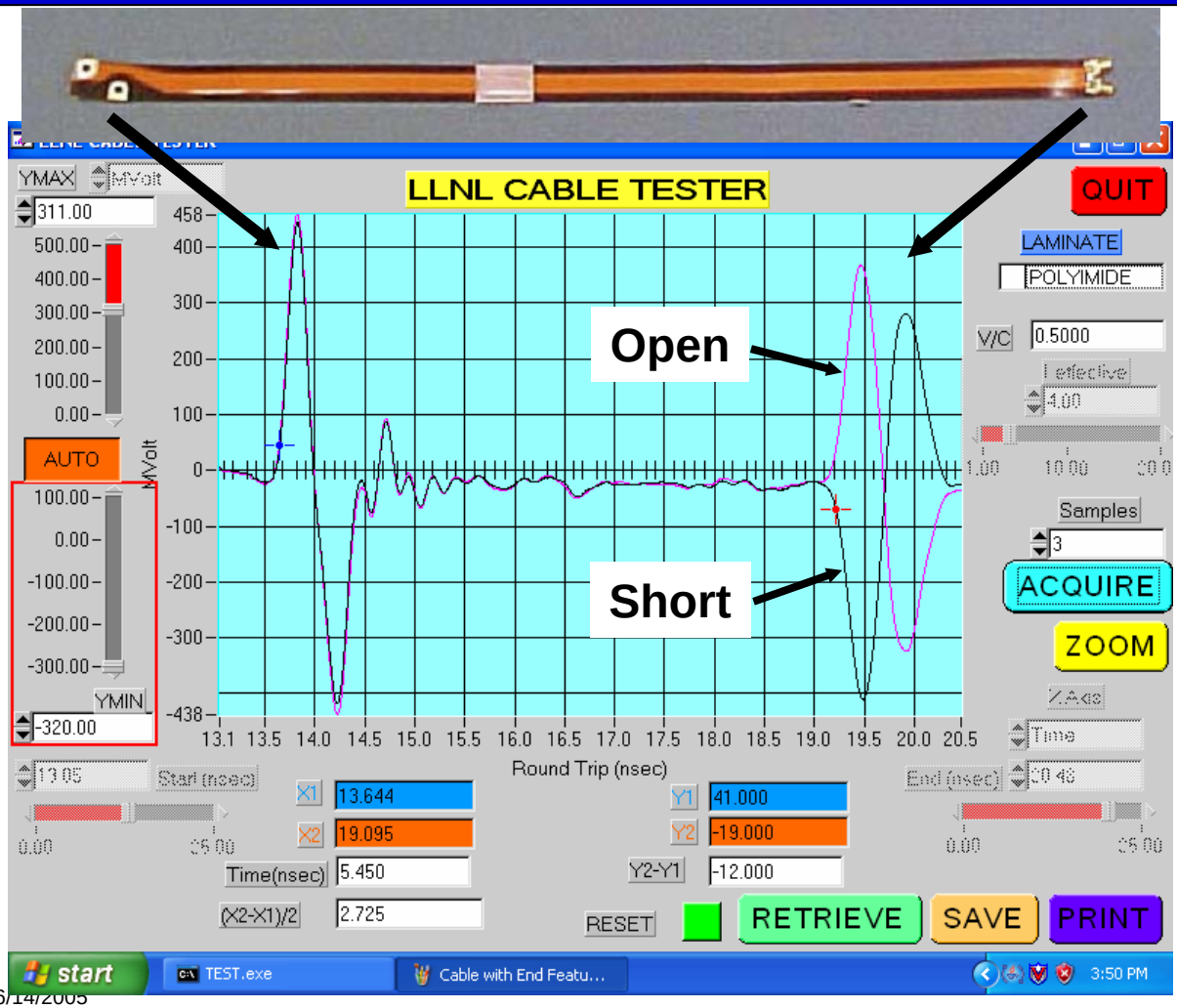
Breadboard TDR at PSPL (cont)



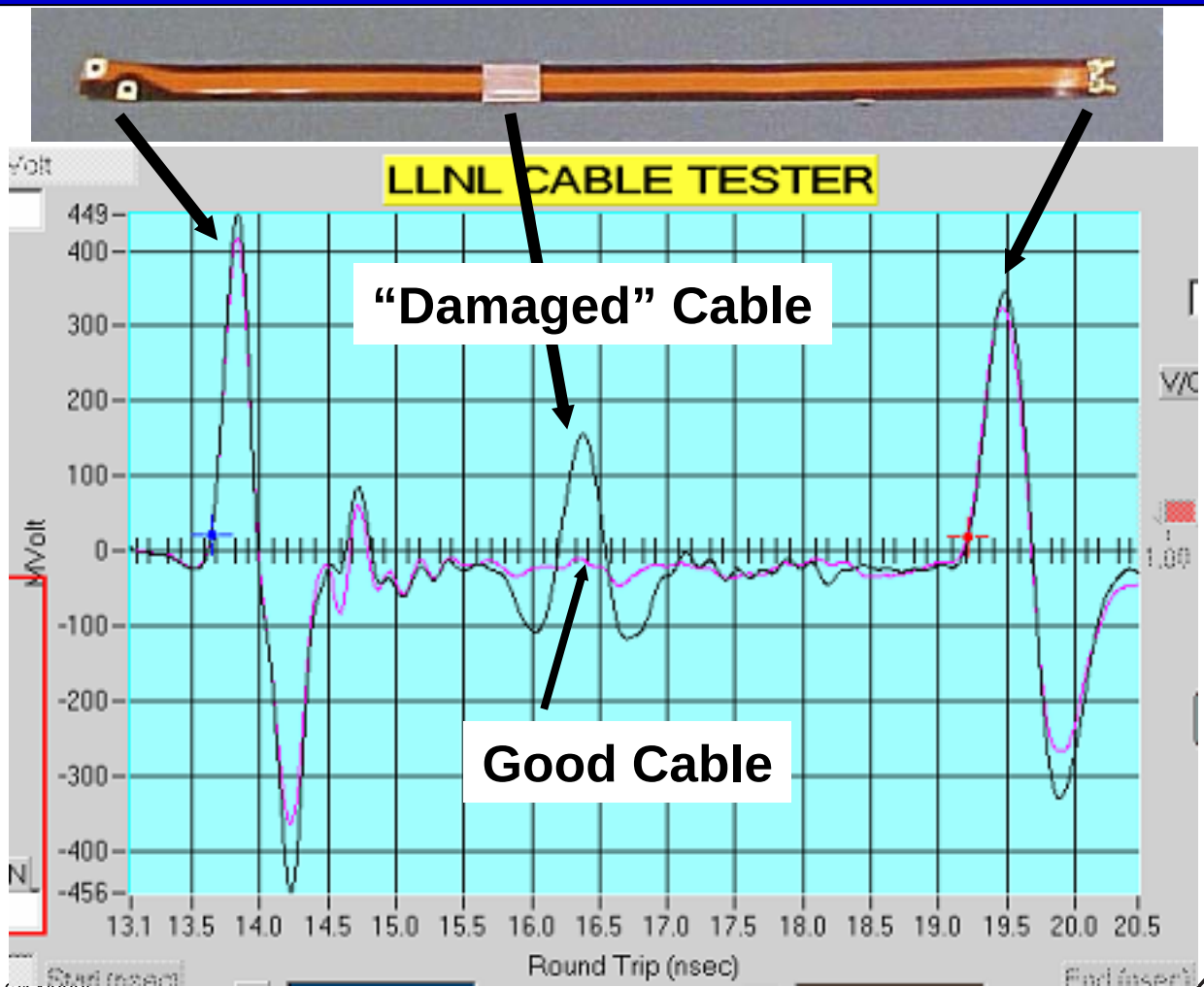
Pulse Insertion Unit: Design A



Good Cable: Open and Short



Capacitive Discontinuity



Cable Insulator Lab

Insulator #1


INSULTOR #1
POWER
OFF
ON
Force (lbs)
00480
Front Gap (mils)
-0.02
Back Gap (mils)
2.70

Cable Insulting Test Plan

- Deform cables with metal dowels of various diameters from 1/32” to 1/4”
- Vary the load to inflict increasing deformation
- Record TDR signature
- Hi-pot the cable to determine voltage breakdown
- Purpose:
  - Determine what cable insult leads to cable failure
  - Develop a matrix of TDR signatures for known insults
  - Use TDR signatures for software analysis development

Software Development

- **Analysis software (LLNL)**
  - **Automatically, in real time analyze TDR signature**
  - **Generate a “Pass” or “Fail” display**
- **Control software (Pantex)**
  - **Control TDR cable tester**
  - **Insure all safety features are in place and working**
  - **Apply power to cable under test**
  - **Insure PIU is properly connected**
  - **Command TDR measurement**
  - **Turn off power**

Analysis Software Considerations

- **PFA = P(False Alarm) must be very low, because the cost of a false alarm is very high**
- **PMISS = P(Miss) must be very low, because the cost of a miss is very high**
- **Model and conduct controlled experiments with various cable "geometric" configurations (bends, twists, routing schemes, etc.) ==> The goal is to increase our understanding of failure modes**

Safety Considerations

- With the transformer coupling there is no DC path to the DUT for the stimulus
- The TDR signal is an impulse of very limited duration, ~300 ps
- Pulse generator is an “inductor-to-ground” topology (no capacitive storage)
- The peak current in the DUT is 50 mA, the rms current is ~350μA
- Both source and sampler have resistive limiters

Safety Considerations

- Operation from an energy limited source, 2850mAh, 1.5 V x 6 AA battery pack
- DC current limited to 10 mA to all circuit blocks closest to the Pulse Insertion Unit
- On demand pass/fail test of current limiters
- Sampling diodes are “self-biased” (no DC bias)

Status: June 2005

- TDR Proof-of-Concept successfully demonstrated
- Battery-powered TDR prototype scheduled for delivery by August 2005
- TDR cable tester designed for use with Nuclear Explosives
- Pantex fully engaged in planning TDR integration during weapon disassembly and assembly